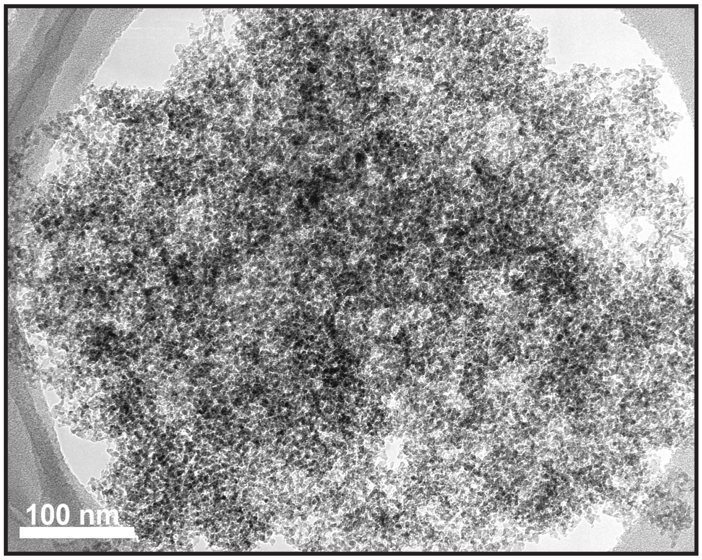
Industrial Materials For The Future

Project Fact Sheet

Advanced Nanoporous Composite Materials for Industrial Heating Applications

Nanoporous aerogel-based materials can provide improved insulation for furnaces and other industrial heating and cooling applications

Industrial process heating comprises 17% of the industrial energy consumption in the United States. Materials use for process-heating technologies vary from fire bricks to highly specialized materials for specific environments. This project seeks to develop new advanced nanoporous ceramic materials for increasing the energy efficiency of industrial process-heating applications. The new materials to be developed are based on sol-gel processing, supercritical drying, chemical vapor infiltration, and advanced packaging techniques. The aerogel-based composites are well placed to provide a new class of materials for these applications. New nanoporous ceramics based on alumina, mullite, zirconia, silica, and others will be prepared from single and mixed metal alkoxides. High-temperature infrared opacification will be achieved by the use of fiber and powder additions to the materials. Chemical vapor infiltration of additional phases to increase strength and density will also be explored. These new materials will provide improved insulation in furnaces and other industrial applications that will substantially reduce energy loss and improve equipment lifetime.



Electron micrograph of an aerogel-derived alumina-chromia composite material useful for high-temperature insulation applications. The image was obtained after a 60-minute heat treatment at 1000°C. The microstructure of the aerogel is relatively unaffected by the thermal processing.

Benefits

- Improved insulating materials will reduce heat losses from furnaces, thereby reducing the energy required for industrial production processes.
- Improved performance from advanced refractory and insulating materials will increase the efficiency of primary energy use, reduce fossil fuel required to produce the energy, improve the lifetime of materials in process environments, and lead to environmental benefits (i.e., reduced CO_2).

Applications

This project seeks to develop new high-performance insulation materials for use in industrial heating applications, including glass melting, steel production, metalcasting, and heat treating. The major focus of this project is on optimizing a specific aerogel or aerogel composite material to the precise thermal, mechanical, and chemical requirements of a given industrial process. Insulation and refractory applications for furnaces and other process heating systems can occur in the following IOF industries:

- **Aluminum,**
- **Chemical,**
- **Glass,**
- **Metalcasting,**
- **Petrochemical,** and
- **Steel,**

and in the following supporting industries:

- **Carbon,**
- **Heat Treating,** and
- **Process Heating.**

Project Description

Goal: The goal of the project is to develop new insulating mesoporous composite materials for process-heating applications. The major objective of this project involves developing aerogel composite materials that retain the advantageous properties of standard aerogels while increasing their mechanical and chemical compatibility properties to the levels necessary to meet the needs of various IOF industries.

Issues: For many years, insulation for use in industrial process environments has been a commodity. More recently, various domestic firms have begun to develop specialty materials for specific applications. One of the hurdles to be overcome in this project is to develop new, low-density materials that can operate at high temperatures and resist to molten metals and slags.

Approach: The approach for creating composite materials with tailored thermal and mechanical properties is based on sol-gel technology, which will be used to create refractory multicomponents from a porous monolithic gel, followed by supercritical solvent extraction. Post-processing techniques, including chemical vapor infiltration and advanced packaging processes, will also be developed. The packaging processes include the incorporation of fibrous or particulate materials as mechanical enhancements and infrared opacifants, exterior dense oxide coatings, and shaping/forming processes. Aerogels similar in composition to the oxide ceramics used today for refractories will be prepared, and their thermal and mechanical properties will be evaluated. Advanced composite structures will be prepared and similarly analyzed. The emphasis will be on identifying and preparing candidate materials optimized for specific applications identified through collaboration with representatives from the IOF industries and material suppliers.

Potential payoff: Improved insulating materials will reduce heat losses from furnaces and other process heating applications, thereby lowering the energy required for industrial production processes. Improved performance from advanced refractory and insulating materials will (1) increase the efficiency of primary energy use, reducing the fossil fuel required to produce the energy; and (2) improve the lifetime of materials in process environments, resulting in lower replacement costs. Reduced impurities and careful choice of materials may also lead to reduction of unwanted compounds in melts and the need to remove them. Environmental benefits are anticipated, leading to reduced emissions (i.e., reduced CO_2).

Progress and Milestones

- Survey existing refractory and insulating materials used in the process heating industry.
- Perform the synthetic chemistry to produce gels of the desired materials, incorporating fibers and powders for strength and improved thermal performance.
- Extract solvents from the candidate materials to achieve an open-pore geometry.
- Where desirable, apply chemical vapor infiltration to obtain a specific composite material and density.
- Evaluate various form factors for aerogel insulation, including monoliths, granular compacts, and additions to standard materials.
- Evaluate the physical, thermal, and microstructural properties of the materials.
- Work with representatives from the IOF industries to test the new materials in industrial processes and evaluate results.

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